A Comparative Study of Algorithms for A/D Converter Performance Evaluation by Statistical Analysis

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Abstract

Three algorithms based on statistical analysis (histogram testing) are analysed: comparison with the theoretical histogram (method1), determination of transition levels by means of histogram (method 2), normalised transfer function (method 3). Simulations are performed with a perfect ADC stimulated by a noisy input signal. The algorithms are compared in terms of DNLE mean value of the estimated DNLE (estimation bias) and, of the standard deviations of DNLE and INLE estimates.

Introduction

Statistical analysis is commonly used to measure the input-output parameters of an ADC, particularly the differential and integral linearity errors (DNLE, INLE), Various algorithms based on statistical analysis allow the evaluation of these parameters, but their robustness in presence of noisy input signal and imperfect coverage of the quantization cell associated with the maximum and minimum codes, i_{max} and i_{min}, were not studied [1]. The stimulus commonly used in statistical analysis is a sine wave of amplitude A and offset O, whose probability function is given by:

$$p_{sin}(V) = \left(\pi\sqrt{A^2-(V-O)^2}\right)^{-1} \qquad (1)$$

and the probability of obtaining code i at the output of an ideal ADC, with reference to the position of decision levels Vt_i, Vt_{i+1} is:

$$p_{th}(i) = \pi^{-1}\left\{\arcsin\left(\left(Vt_{i+1}-O\right)/A\right)-\arcsin\left(\left(Vt_i-O\right)/A\right)\right\} \qquad (2)$$

Algorithms

Method 1: It may be applied only when it is "a priori" known that the INLE is small and based on the comparison of the observed code frequencies with those expected from an ideal ADC with the same resolution applying the same input signal, DNLE and INLE are calculated by:

$$\begin{cases} DNLE(i)=\left(p(i)-p_{th}(i)\right)/p_{th}(i) \\ INLE(i)=\sum_{j=i_{min}}^{i} DNLE(j) \end{cases} \qquad (3)$$

Method 2: The probability of obtaining a code smaller than or equal to i, expressed by (1) and (2), function of the decision level Vt_{i+1}, is:

$$p_{th}(i) = \sum_{j\le i} p_{th}(j) = \frac{1}{\pi}\arcsin\left(\left(Vt_{i+1}-O\right)/A\right)+\frac{1}{2} \qquad (4)$$

Using the experimental probability of each code and (4) it is possible to calculate all the decision levels, after the estimation of A and O as reported [2]. In this case linearity errors are calculated by:

$$DNLE(i) = \left[Vt_{i+1}-Vt_i\right]/q_{ref} - 1\ ;\ q_{ref} = 1\ \text{lsb} \qquad (5)$$

The estimation of INLE(i) is accomplished by subtracting the measured and theoretical decision levels for each code. Alternatively integral linearity can be calculated using (3).

Method 3: To eliminate the influence of the error in the estimation of A and O, the normalised transfer function principle is introduced. In this case all transition levels are calculated by normalising the spanned input range [O-A, O+A], to the range [-1, +1]. The determination of DNLE and INLE proceeds in close analogy with method 2. The reference quantum width to be substituted in (4) is:

$$q_{ref} = \left(Vtn_{i_{max}} - Vtn_{i_{min}+1}\right)/\left(i_{max}-i_{min}+1\right) \qquad (6)$$

where i_{max} and i_{min} points to the codes most frequently observed at the two extremities of the bath tub histogram.

Simulation Results

The above three methods were compared in terms of the reliability of the estimates of linearity errors in the presence of noise, when the measured histogram does not show abrupt transitions to zero outside the codes i_{min}, i_{max} (edge effect). An ideal 8bit ADC simulated by a noisy input sinusoid was simulated. Simulation results show that the third method is most reliable, whether the histogram is saturated or not. With the order two methods sensible systematic errors in DNLE are observed, which depend on the amplitude of the signal and lead to inaccurate estimate of the INLE. The repeatability of the estimates, a measure of the sensitivity to noise, which is revealed by the standard deviation of DNLE and INLE, is similar for methods 2 and 3.

References

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